Table 23. Listing of Manufacturers and Contractors of the Fold and Form Method for Close-fit Lining.

Manufacturer/ Contractor	Telephone Number	Fax Number	Address	Coverage Area	Contact Person
American Pipe & Plastics, Inc. [1]	(607) 775-4340	(607) 775-2707	P.O. Box 577 Binghamton, NY 13902	National	N/A[2]
AM-Liner East, Inc.	(703) 430-4120	(703) 721-4977	1402 Shepard Dr. Suite 101 Sterling, VA 20164	PA, MD, NC, SC, VA, Wash. DC, FL,	David Giuliani
Associate Distributors, Inc.	(800) 737-0531	(314) 781-3240	P.O. Box 9172 St. Louis, MO 63117	AR, IA, MO, parts of IL	N/A
Atlantic Coast Contractors, Inc.	(704) 483-7120	(704) 483-7310	7680 Townsend Dr. P.O. Box 463 Denver, NC 28037	N/A	N/A
Boatman Construction	(615) 793-6721	(615) 793-6722	430 Dick Buchanan Dr. P.O. Box 868 Lavergne, TN 37086	AL, FL, GA, KY, MS, NC, SC, TN	N/A
C & C Service Supply	(800) 280-7981	(254) 662-3945	P.O. Box 11305 Waco, TX 76716	TX	N/A
Cisco Specialty Products	(714) 633-0698	(714) 633-2831	137 West Bristol Lane Orange, CA 92865	CA, NV	N/A
Columbia Pumping-Environmental Services Division	(800) 510-1103	(509) 547-4841	1005 S. Maitland Ave. Pasco, WA 99302	OR, parts of ID, WA	N/A
Con Line Co.	(540) 389-2927	(540) 387-4365	P.O. Box 6068 Roanoke, VA 24017	VA, WV, parts of NC	N/A
Darby Pipeline Rehabilitators, Inc.	(740) 477-8600	(740) 477-9865	6790 Brooksmiller Rd. Circleville, OH 43133	OH, parts of IN, KY, MI, WV	N/A
D.A. Van Dam & Associates	(888) 818-0016	(330) 759-9661	1540 Fisher Dr. Hubbard, OH 44425	OH, MI, parts of PA	N/A
Eastern Pipe Service	(603) 424-4600	(603) 424-466?	26B Columbia Circle Merrimack, NH 03054	CT, ME, MA, NH, RI, VT	N/A
Environmental Pipeliners, Inc.	(614) 792-9295	(614) 792-0426	6200 Eiterman Rd. Dublin, OH 43016	KY, IN, OH, Western PA	Lori Jackson
Five V Corporation	(770) 939-3924	(770) 934-7629	P.O. Box 2722 Tucker, GA 30085	GA, parts of TN	N/A
Greenville Rooter, Inc.	(864) 848-0105	(864) 877-3418	P.O. Box 575 Greer, SC 29652	GA	Floyd Miner
Ground & Pipe Technologies	(334) 388-5640	(344) 264-8980	1120 Parker St. P.O. Box 9204 Montgomery, AL 36108	AL, FL	N/A
Hi-Tech Pipeline Services, Inc.	(831) 757-2774	N/A	20520 Spence Rd. Salinas, CA 93908	Northern CA, NV	Billy Haendiges
InfraCor, Inc.	(804) 272-6600	N/A	7400 Beaufont Springs Dr, Suite 415 Richmond, VA 23225	N/A	N/A
InfraCorps of Virginia	(877) 231-3426	(804) 231-9613	2210 East Belt Blvd. P.O. Box 24205 Richmond, VA 23224	VA, parts of NJ, NY, WV	N/A
InfraTech International	(800) 568-1707	(717) 763-8665	3605 Hartzdale Dr. Camp Hill, PA 17011	PA, MD, parts of NJ, NY, WV	N/A
Insituform Technologies, Inc. [1]	(800) 234-2992	(636) 519-8010	702 Spirit 40 Park Dr. Chesterfield, MO 63005	National	N/A
J.F. Pacific Liners, Inc.	(707) 446-8222	(707) 447-3361	70 Union Way Vacaville, CA 95687	Northern CA	Jay Fox
Jim Jolly Sales, Inc.	(847) 458-0382	(847) 458-0383	3571 Persimmon Dr. Algonquin, IL 60102	IL, WI, IN	N/A

[1]Designates company headquarters, [2]N/A – not available

Table 23 (cont.). Listing of Manufacturers and Contractors of the Fold and Form Method for Close-fit Lining.

Manufacturer/ Contractor	Telephone Number	Fax Number	Address	Coverage Area	Contact Person
Jones Bros, Inc.	(615) 754-4710	(615) 758-9934	P.O. Box 727 Mt. Juliet, TN 37121	TN	N/A[2]
Kana Pipeline, Inc.	(714) 986-1400	(714) 986-1416	172 East Orangethrope Ave. Placentia, CA 92870	CA, parts of NV	N/A
Lash Contracting	(518) 783-7832	(518) 783-7341	794 Watervliet-Shaker Rd. Latham, NY 12110	Upstate NY	Robert Lashway
Lauderdale Environmental Services	(256) 765-0036	(256) 765-0036	614 North Poplar St. Florence, AL 35630	AL	N/A
MaS Sales, Inc *North Carolina Office*	(704) 482-9647	(704) 482-9647	1429 Fallston Rd. Shelby, NC 28150	NC	N/A
MaS Sales, Inc. *South Carolina Office*	(843) 692-0669	(888) 627-1017	819 Forest Dr. Myrtle Beach, SC 29577	NC, SC	N/A
Miksis Services, Inc	(888) 867-5848	(707) 937-8173	P.O. Box 591-I Healdsburg, CA 95448	CA	N/A
Miller Pipeline Corporation	(317) 293-0278	(317) 293-8502	8850 Crawfordville Rd. Indianapolis, IN 46234	N/A	N/A
Next Generation Renovation, Inc.[1]	(800) 267-9810	(705) 645-1122	3442 Lauderdale Dr., Suite 212 Richmond, VA 23233	National	N/A
Northwest Industrial Equipment	(253) 872-6060	(243) 872-6059	22023 70th Ave. South Kent, WA 98032	ID, OR, WA	N/A
PEC, Inc.	(406) 447-5030	(406) 447-5046	825 Custer Helena, MT 59604	MT, ND, SD, WY, parts of WA	N/A
PIM Corporation	(800) 293-6224	(732) 469-8959	201 Circle Dr. No. Suite 106 Piscataway, NJ 08854	N/A	N/A
Raleigh & Associates	(623) 972-9238	(623) 972-9250	11124 California Ave. Youngtown, AZ 85363	AZ	N/A
Sancon Technologies Inc.	(714) 902-0115	(714) 902-0121	5881 Engineer Dr. Huntington Beach, CA 92649	Southern CA	Nick DiBenedetto
Southland Contracting	(817) 572-3331	(817) 293-5065	P.O. Box 40664 Fort Worth, TX 76140	TX, parts of CA, OK	N/A
Tele Environmental Systems	(970) 945-2866	(970) 625-8315	1419 Airport Rd. Rifle, CO 81650	WY, UT, CO	Charlie Lanphear
Triad Western Constructors	(970) 565-4257	(970) 565-1057	512 North Broadway Cortez, CO 81321	CO, NM, parts of TX, AZ	N/A
Tri-State Utilities	(757) 366-9505	(757) 366-5150	2111 Smith Ave. Chesapeake, VA 23320	VA, NC	N/A
Ultraliner, Inc.	(256) 831-5515	(256) 831-5575	P.O. Drawer 3630 201 Snow St. Oxford, AL 36203	AL, parts of FL, KY, MS, NC, SC, GA, TN	N/A
Ultraliner Sales, Inc.[1]	(256) 835-6767	(256) 835-6766	P.O. Drawer 3630 201 Snow St. Oxford, AL 36203	National	N/A
Utility Lining Corp.	(631) 242-5155	(631) 242-4146	1940 Deer Park Ave. Deer Park, NY 11729	NYC	Gregg Penza
Val Kotter and Sons	(435) 734-9598	(435) 734-9870	1035 West Forest St. Brigham City, UT 84302	UT, Parts of ID, NV	N/A
Valley Isle Pumping Inc.	(808) 242-5692	(808) 244-3596	RR 1, Box 146E Wailuku, HI 96793	HI	N/A
Williams Testing	(888) 921-7473	(941) 925-1901	P.O. Box 15877 Sarasota, FL 34277	Southwest FL	Jean Dunlop

[1]Designates company headquarters, [2]N/A – not available

SPIRALLY WOUND LINING

Description

Spirally wound lining uses interlocking profile strips, most commonly made from PVC, to line a deteriorated culvert. Coiled, interlocking profile strips, shown in Figure 15, are fed through a winding machine that mechanically forces the strips to interlock and form a smooth, continuous, spirally wound liner. During the interlocking process, a sealant is applied to each joint to form a watertight seam. As the material is wound and snapped together, it is forced into the existing culvert.

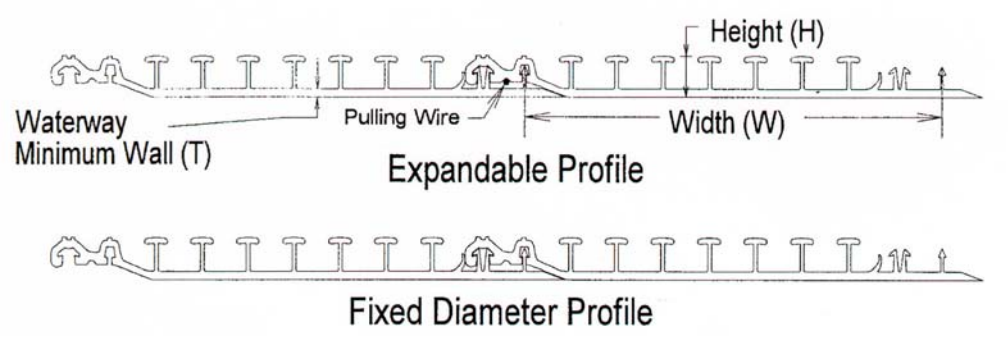

Figure 15. Drawings. Expandable and Fixed Diameter Profile Strips.[(64)]

Generally, the liner is wound and inserted from existing manholes without excavation. For larger diameter culverts (larger than 91 centimeters (36 inches)), preformed panels are spirally wound, rather than profile strips. Grouting of the annular space is generally required when fixed diameter profile strips are used. If expandable profile strips are used, grouting is unnecessary. Figure 16 presents the expandable profile liner and the fixed diameter profile liner requiring annular grouting.

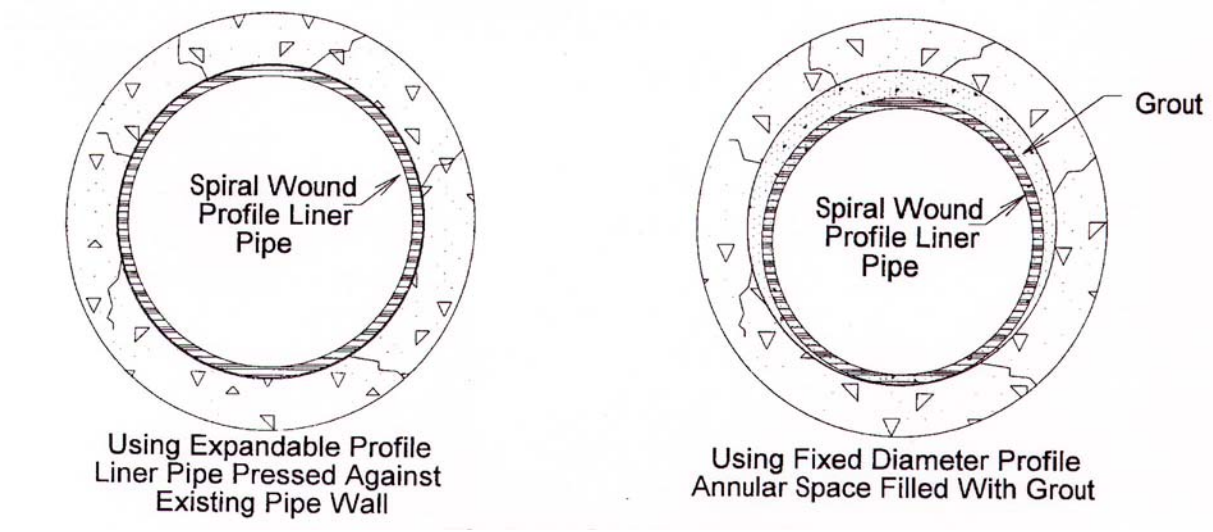

Figure 16. Drawings. Inserted Expandable and Fixed Diameter Spirally Wound Lining.[64]

Effective Uses, Advantages, and Limitations

General characteristics and effective uses of the spirally wound lining are presented in Table 24. Advantages and limitations associated with spirally wound lining are presented in Table 25.

Table 24. General Characteristics and Effective Uses of Spirally Wound Lining.[5,6,7]

Applications	Diameter Range	Liner Material[1]	Maximum Installation
Gravity Pipelines Only	100 - 3,050 millimeters (4 - 120 inches)	PE, PVC, PP, PVDF	Unlimited

[1]PE – Polyethylene, PVC – Poly(Vinyl Chloride), PP – Polypropylene, PVDF – Poly-Vinylidene Chloride

Table 25. Advantages and Limitations of Spirally Wound Lining.[5,6]

Advantages	Limitations
Liner formed on site	Continuous fusion or sealant of joints is required
No pipe storage on site required	
Any diameter (within range of winding machine) can be selected	Requires trained personnel to operate winding machine and equipment
Grouting is not required if expandable joints are used	Grouting usually required if fixed diameter joints are used
Capable of accommodating large radius bends	
Accommodating of diameter changes may be possible	Reduction in flow capacity may be significant
Flow bypass is not always required	Lateral connections, service connections, and termination ends may require watertight sealing
Excavation is usually not required	

Costs

According to the USFS Draft Report on trenchless technology for Forest Service culverts,[9] the range of costs for spiral wound lining is approximated to be $100 per linear foot for 45.7-centimeter (8-inch) diameter pipes and $750 per linear foot for the largest diameters placed by hand.

General Installation Guidelines

A general list of installation guidelines for spirally wound lining is provided below:[5,14,64,65]

1. Prior to entering access areas and performing inspection or cleaning operations, test the atmosphere in the insertion pits to determine the presence of toxic or flammable vapors, or the lack of oxygen in accordance with local, State, or Federal safety regulations.
2. Thoroughly clean the existing culvert. Gravity culverts should be cleaned with hydraulically powered equipment (high-velocity jet cleaners).
3. Inspect the existing culvert to determine the location of any conditions that may hinder proper insertion of the spirally wound lining, such as protrusions, collapsed sections, deflected joints, etc.
4. Clear line obstructions discovered during the inspection prior to inserting the liner. Angles that can be negotiated depend upon a variety of factors. Depending upon the method of installation and type of profile strip used, diameter changes in the existing culvert may be accommodated for a determination of whether a bend or diameter changes can be accommodated, consult the manufacturer.
5. Installation does not require a dry pipeline, thus flow bypass may not be required. If necessary, flow bypass should be carried out in the necessary fashion.
6. If required or recommended by the manufacturer, excavate an insertion pit to comfortably accommodate all equipment necessary for installation.
7. Insert winding machine within insertion pit (or manhole) and orient the machine so that the liner can be spirally wound and properly inserted directly into the existing culvert. As the profile strip is wound in the machine, place the required sealant or adhesive within the primary and secondary locks of the locking configuration at the edge of the strip (unless already in place). Figure 17 presents the installation procedure of a fixed diameter spirally wound liner.

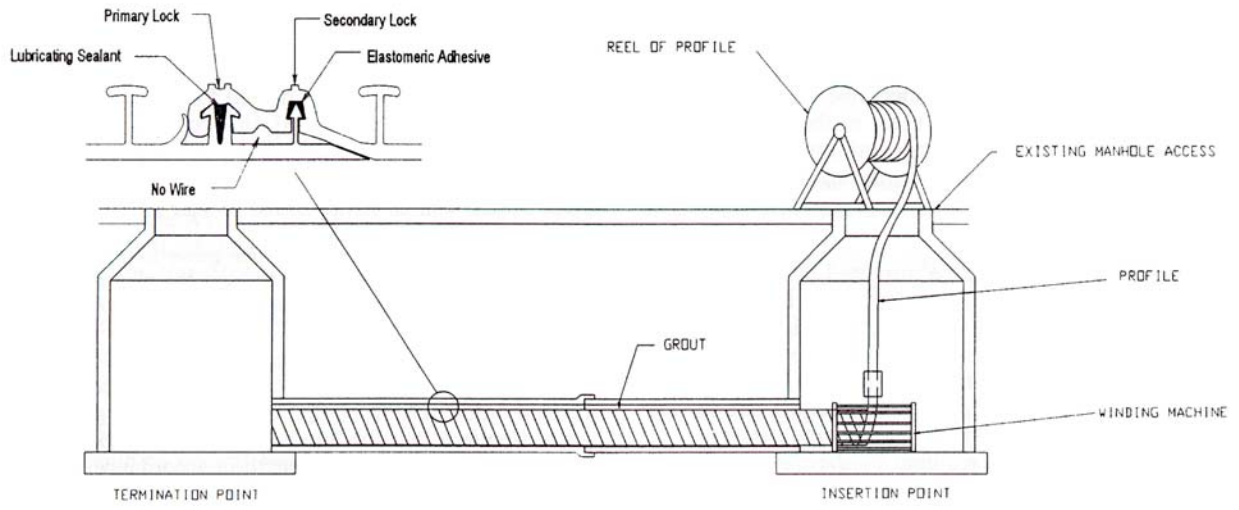

Figure 17. Drawing. Installation of Fixed Diameter Spirally Wound Lining.[64]

8. The wound liner is to be expanded, torsionally restrain the liner at the termination point. To accomplish this, release a specific length of the inserted spirally wound lining at the termination point by pulling the wire out of the expandable interlocked joint. Recommence the winding operation, which will create a torque to the released end, causing a radial growth over the released length of the liner. Allow the growth to continue until the released end of the liner is pressed against the existing culvert, causing the growth to cease. Repeat this process until the spirally wound lining is pressed against the full length of the existing culvert. Obtain and follow specific guidelines provided by the manufacturer for installation if applicable. Figure 18 presents the installation of an expandable spirally wound lining.

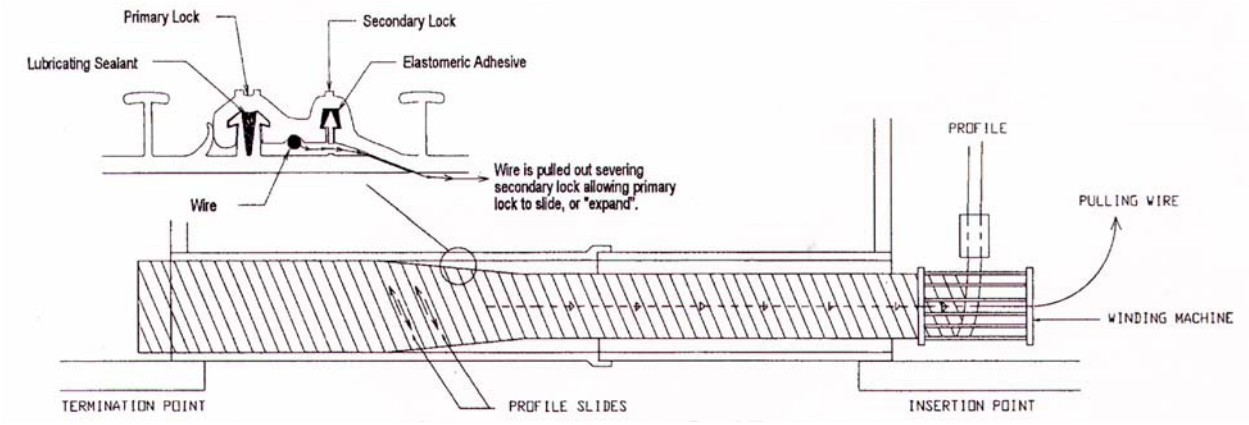

Figure 18. Drawing. Installation of an Expandable Spirally Wound Lining.[64]

9. If the job requires the use of profile strips to be provided in the form of panels, cut and trim the panels to fit as near as practical to the internal diameter of the existing culvert or to produce the required annulus. Place the panels square with the culvert wall, circumferentially, and lock adjacent panels together as specified by the manufacturer. Seal termination joints with a manufacturer-supplied connecter and approved sealant.
10. Inspect the completed installation by closed-circuit TV or manually if the diameter permits man-entry. The spirally wound lining should be continuous over the entire length.
11. If leakage or other testing is required, perform testing to specifications and prior to the re-opening of lateral and service connections.
12. Reconnect lateral and service connections with a television camera and a remote- control cutting device or manually where the diameter permits man-entry. After reopening the lateral and service connections, seal the annular space between the liner and the existing culvert at the termination points with a watertight seal.
13. If grouting is necessary, inject grout into the annular space between the existing culvert and liner through openings in the end seals, at reconnected service connections, or through holes drilled into the liner at appropriate points. Carry out the grouting procedure in one of two ways. Either apply the grout in a series of lifts/stages or apply the grout continuously. Appropriate standards or the manufacturer should be consulted further for more specific information pertaining to grouting procedure.
14. Finally, restore flow if bypass was required and initiate site cleanup.

Annular Grouting

Annular Grouting is generally required for spirally wound lining in cases where the liner is of fixed diameter or does not expand to fit tightly against the existing pipe wall. In addition to the standards and specifications listed in Table 3, the following list of related standards are associated with annular grouting of spirally wound lining:

- ASTM F 1741 – Standard Specification for Installation of Machine Spiral Wound Poly(Vinyl Chloride) (PVC) Liner Pipe for Rehabilitation of Existing Sewers and Conduits (2001)[64]
- ASTM F 1697 – Standard Specification for Poly(Vinyl Chloride) (PVC) Profile Strip for Machine Spiral-Wound Liner Pipe Rehabilitation of Existing Sewers and Conduit (1996)[66]
- ASTM F 1698 – Standard Practice for Installation of PVC Profile Strip Liner and Cementitious Grout for Rehabilitation of Existing Man-Entry Sewers and Conduits (1996)[65]
- NASSCO Specification of Profiled PVC Lining, Man-entry Sewers (as provided by Danby™ of North America, Inc. for the Danby™ -Sliplining/PL Process)[14]
- NASSCO Specification of Spiral Wound Pipe, 8 inch to 24 inch, Profiled PVC (as provided by Danby™ of North America, Inc. for the Danby™ -TL Process) (1999)[14]

Standards/Specifications

Table 26 presents the current standards and specifications associated with the spirally wound lining method.

Table 26. Standards Associated with Spirally Wound Lining.[14,23]

Standard/Specification	Description
ASTM F 1697 – Standard Specification for Poly(Vinyl Chloride) (PVC) Profile Strip for Machine Spiral-Wound Liner Pipe Rehabilitation of Existing Sewers and Conduit (1996)[66]	Covers the requirements and test methods for materials, dimensions, workmanship, stiffness factor, extrusion quality, and a form of marking for extruded PVC profile strips for machine-made field fabrication of spirally wound pipe liners.
ASTM F 1698 – Standard Practice for Installation of PVC Profile Strip Liner and Cementitious Grout for Rehabilitation of Existing Man-Entry Sewers and Conduits (1996)[65]	Describes the procedures for the rehabilitation of sewer lines and conduits by the installation of a field-fabricated PVC liner. After installation of the liner, cementitious grout is injected into the annular space between the liner and the existing sewer or conduit.
ASTM F 1735 – Standard Specification for Poly(Vinyl Chloride) (PVC) Profile Strip for PVC Liners for Rehabilitation of Existing Man-Entry Sewers and Conduits (2001)[67]	Covers the requirements and test methods for materials, dimensions, workmanship, extrusion quality, and a form of marking for extruded PVC profile strips used for field fabrication of PVC liner for existing man-entry in vertical sewer and conduit rehabilitation.
ASTM F 1741 – Standard Specification for Installation of Machine Spiral Wound Poly(Vinyl Chloride) (PVC) Liner Pipe for Rehabilitation of Existing Sewers and Conduits (2001)[64]	Describes the procedures for the rehabilitation of sewer lines and conduits by the installation of a field-fabricated spiral wound liner pipe into an existing pipeline. After insertion, the spiral wound liner pipe is expanded until it presses against the interior surface of the existing pipeline, or, alternatively, the spiral wound liner pipe is inserted as a fixed diameter into the existing pipeline and is not expanded, and the annular space between the spiral wound liner and existing pipe is grouted.
NASSCO Specification of Spiral Wound Pipe, 8 inch to 24 inch, Profiled PVC (as provided by Danby™ of North America, Inc. for the Danby™ -TL Process) (1999)[14]	Describes the specifications, design considerations, materials, equipment, and installation of spirally wound PVC profile strip liners.
NASSCO Specification of Spiral Wound Pipe, 8 inch to 36 inch, Profiled PVC (as provided by Rib Loc® Group Limited for Rib Loc® Expanda Pipe Process) (1999)[14]	Describes the specifications, design considerations, materials, equipment, and installation of spirally wound PVC profile strip liners.
NASSCO Specification of Profiled PVC Lining, Man-entry Sewers (as provided by Danby™ of North America, Inc. for the Danby™ -Sliplining/PL Process) (1999)[14]	Describes the specifications, design considerations, materials, equipment, and installation of spirally wound PVC panels.

In addition to the four (4) specific ASTM standards presented in Table 26, the following list of related standards were also associated with spirally wound lining:

- ASTM C 39 – Test Method for Compressive Strength of Cylindrical Concrete Specimens[68]
- ASTM C 969 – Practice for Infiltration and Exfiltration Acceptance Testing of Installed Precast Concrete Pipe Sewer Lines[69]
- ASTM D 618 – Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[48]

- ASTM D 790 – Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials[26]
- ASTM D 883 – Terminology Relating to Plastics[70]
- ASTM D 1600 – Terminology for Abbreviated Terms Relating to Plastics[27]
- ASTM D 1784 – Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds[60]
- ASTM D 2122 – Test Method for Determining Dimensions of Thermoplastic Pipe and Fittings[28]
- ASTM D 2152 – Test Method for Degree of Fusion of Extruded Poly(Vinyl Chloride) (PVC) Pipe and Molded Fittings by Acetone Immersion[61]
- ASTM D 2240 – Test Method for Rubber Property – Durometer Hardness[71]
- ASTM F 412 – Terminology Relating to Plastic Piping Systems[31]
- ASTM F 1057 – Practice for Estimating the Quality of Extruded Poly(Vinyl Chloride) (PVC) Pipe by Heat Reversion Technique[63]
- ASTM F 1417 – Test Method for Installation Acceptance of Plastic Gravity Sewer Lines Using Low-Pressure Air[42]

Contractors and Manufacturers

A listing of manufacturers and contractors of spirally wound lining is presented in Table 27.

Table 27. Listing of Manufacturers and Contractors of Spirally Wound Lining.

Manufacturer/ Contractor	Telephone Number	Fax Number	Address	Coverage Area	Contact Person
BRH-Garver, Inc.	(713) 921-2929	(713) 921-2487	5402 Lawndale Houston, TX 77023	KS, LA, NM, OK, TX	N/A[2]
Danby Pipe Renovation[1]	(919) 467-7799	(919) 467-7754	P.O. Box 5127 Cary, NC 27512	National	N/A
PPR Pipe Rehabilitation, Inc.	(714) 428-4515	(714) 428-4519	2615 S. Rousselle St. Santa Ana, CA 92707	CA	N/A

[1]Designates company headquarters, [2]N/A – not available

CURED-IN-PLACE PIPE LINING

Cured-in-place lining, also known as “in-situ lining,” installations involve the insertion of a flexible fiber tube coated with a thermosetting resin into an existing culvert by hydrostatic or air inversion or by mechanically pulling. Once installed, the resin is cured under ambient conditions or through applied heat provided by circulating stream or hot water throughout the tube. Unlike other lining methods, the flexible fiber lining tube is manufactured to suit specific existing cul-

vert dimensions. Many cured-in-place lining systems are used that differ in tube composition, resin type, installation procedure, and curing process. Flexible fabric and thermosetting resin are the primary components of cured-in-place lining.

For typical installations, the resin is the primary structural component of the system.[5] Resins are categorized into three (3) different categories and are chosen based upon design conditions and the functionality of the deteriorated culvert. The three (3) types of resin categories are unsaturated polyester, vinyl ester, and epoxy. Unsaturated polyester resins are the most widely used resins in cured-in-place lining systems due to their chemical resistance to municipal sewage, excellent workability during installation, and economic feasibility. For industrial and pressure pipeline rehabilitations that require special corrosion and higher temperature performance needs, vinyl ester and epoxy resin systems are used. Epoxy resins are required for the rehabilitation of potable water pipelines.

Cured-in-place lining systems can also be designed and categorized into the three (3) types of lining tubes for installation. These systems consist of felt-based systems, woven hose systems, and membrane systems. Felt-based lining tubes are produced from nonwoven polyester felt that is coated on one face with a layer of elastomer. Due to the varying thickness and introduction of reinforcing fibers during manufacturing, felt-based tubes offer solutions to a wide range of design requirements. Manufactured out of a circular woven, seamless, polyester fiber hose that is coated on one face with a layer of elastomer, woven hose systems are primarily designed to rehabilitate pressure pipelines suffering from corrosion and leakage. Membrane systems are composed of a very thin elastomeric membrane designed for the rehabilitation of leaking, low-pressure gas mains and offer internal corrosion protection. Cured-in-place lining systems can further be categorized based upon the installation process used to install the liner.

Inversion Installation Method for Cured-in-place Lining

Description

Inversion installation method for cured-in-place lining, or inverted-in-place installation method, involves the installation and simultaneous inversion of a thermosetting, resin-impregnated tube into a deteriorated culvert. This method requires the placement of a vertical standpipe, or other apparatus, at the insertion end. After connecting the resin-impregnated tube to the vertical standpipe, the tube is forced through the existing culvert by applying hydrostatic water pressure, or pressurized air/steam, while simultaneously being inverted. As the liner is inverted, the resin allows the liner to attach and conform to the existing culvert walls. Once installed, the thermosetting resin is cured through heat provided by circulating hot water or steam. Figure 19 presents Insituform's cured-in-place lining inversion installation process.

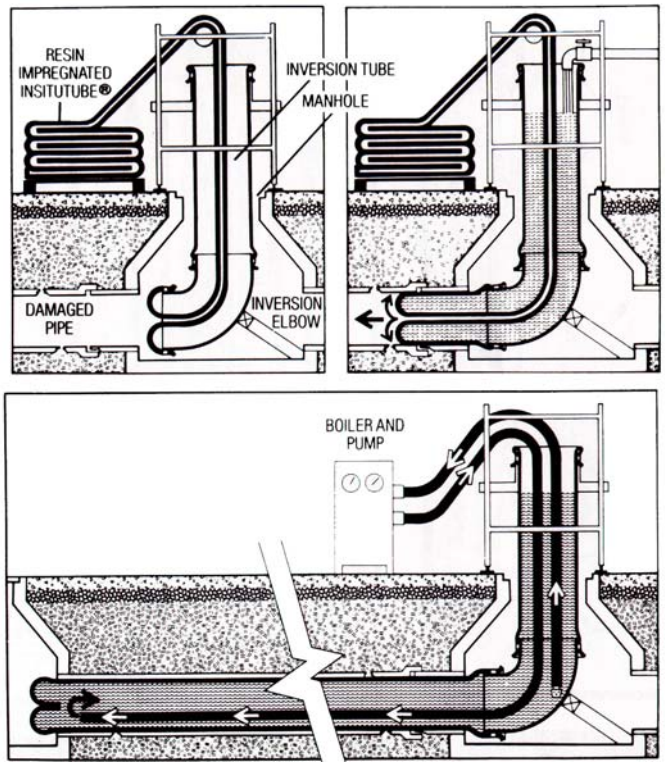

Figure 19. Drawings. Insituform's Cured-in-place Lining Inversion Installation Method.[8]

Effective Uses, Advantages, and Limitations

General characteristics and effective uses of the inversion installation method for cured-in-place lining are presented in Table 28. Advantages and limitations associated with the inversion installation method for cured-in-place lining are presented in Table 29.

Table 28. General Characteristics and Effective Uses of the Inversion Installation Method for Cured-in-place Lining.[5,6]

Applications	Diameter Range	Liner Material	Maximum Installation
Gravity & Pressure Pipelines	100 - 2,700 millimeters (4 - 106 inches)	Thermoset Resin/ Fabric Composite	900 meters (275 feet)

Table 29. Advantages and Limitations of the Inversion Installation Method for Cured-in-place Lining.[5,6,7]

Advantages	Limitations
No joints	Flow bypass is required
Capable of accommodating bends and pipe deformations	Requires trained personnel to operate special equipment
Grouting is not normally required	Tubing must be specially constructed for each project
Minimal or no reduction in flow capacity	Lateral connections, service connections, and termination ends may require watertight sealing
Minor or no excavation required	
Non-circular shapes can be accommodated	Resin requires a long time period to cure
Long installations possible	Styrene monomer-based resins used in making the liner are potentially toxic prior to completion of the curing process
	Possible thermal pollution from the discharge waters used to heat the resin liner

Costs

According to the USFS Draft Report on trenchless technology for Forest Service culverts,[9] the range of costs for inversion installation method for cured-in-place lining is approximated to be $100 per linear foot for 45.7-centimeter (18-inch) diameter pipes and approximately $800 per linear foot or more for the largest diameters.

General Installation Guidelines

A general list of installation guidelines for the inversion installation method for cured-in-place lining is provided below:[14,72]

1. Prior to entering access areas and performing inspection or cleaning operations, test the atmosphere in the insertion pits to determine the presence of toxic or flammable vapors, or the lack of oxygen in accordance with local, State, or Federal safety regulations.
2. Thoroughly clean the existing culvert. Gravity culverts should be cleaned with hydraulically powered equipment (high-velocity jet cleaners).
3. Inspect the existing culvert to determine the location of any conditions that may hinder proper insertion of the cured-in-place lining liner, such as protrusions, collapsed sections, deflected joints, etc.
4. Clear line obstructions discovered during the inspection prior to inserting the liner. Generally, most bend angles and changes in existing culvert diameter can be accommodated. If obstructions cannot be cleared, point repair excavation should be used to remove and repair the obstruction.

5. Vacuum-impregnate the insertion tube with the specified resin under controlled conditions. Apply a resin volume sufficient to fill all voids in the tube material. Add 5% to 10% excess resin to the estimated volume to account for the change in resin volume due to polymerization and migration of resin into cracks and joints in the deteriorated culvert. Lubricate the tube before installation. This can be achieved by applying lubricant to the fluid in the standpipe or by applying lubricant directly to the tube.
6. Bypassing of flow is required, unless flow can be shut off during installation.
7. If inverting the resin-impregnated tube with hydrostatic head, insert the tube into the vertical inversion standpipe. Insert the tube with the impermeable plastic membrane side out, while at the lower end of the standpipe, turn the tube inside out and attach it to the standpipe so that a watertight seal is created. Fill the standpipe with water, creating a sufficient head to cause the tube to invert throughout the pipe and bond to the existing culvert.
8. If inverting the resin-impregnated tube with air/steam pressure, insert the tube into the guide chute with the impermeable plastic membranes side out. Attach the tube to the upper end of the chute so that a seal is created. Obtain the minimum air/stream pressure needed to hold the tube tight against the existing culvert and the maximum allowable pressure from the manufacturer. Apply the appropriate air/steam pressure to cause the tube to invert throughout the pipe and bond to the existing culvert.
9. After inversion is completed, circulate hot water or steam throughout the liner with approved equipment. Equipment should be suited with temperature gages and be capable of circulating the hot water or steam uniformly throughout the liner. The initial cure will occur during the heat-up process. After initial cure, raise the temperature to the resin manufacturer's recommended post-cure temperature. Hold this temperature for the recommended period of time by recirculating the water or steam throughout the liner and heating apparatus. Maintain the recommended pressures throughout the curing process.
10. If heated water was used to cure the resin, drain the heated water from a small hole made in the downstream end and replace with the introduction of cool water into the inversion standpipe. Cool the liner to a temperature below 37.8°C (100°F) before relieving the static head in the inversion standpipe.
11. If air/steam was used to cure the resin, drain the air/steam through a small hole made in the downstream end and replace with the introduction of cool water into the guide chute. Cool the liner to a temperature below 45°C (113°F) before relieving the pressure within the section.
12. Cut and seal the termination ends with a resin mixture compatible with the installed liner if the liner does not fit tightly against the original pipe.
13. Inspect the completed installation by closed-circuit TV or manually if the diameter permits man-entry. The liner should be continuous over the entire length.
14. If leakage or other testing is required, perform testing to specifications and prior to the reopening of lateral and service connections.

15. Reconnect lateral and service connections with a television camera and a remote- control cutting device or manually where the diameter permits man-entry.
16. Finally, restore flow and initiate site cleanup.

Standards/Specifications

Table 30 presents the current standards and specifications associated with the inversion installation method for cured-in-place lining.

Table 30. Standards Associated with the Inversion Installation Method for Cured-in-place Lining.[14,23]

Standard/Specification	Description
ASTM D 5813 – Standard Specification for Cured-In-Place Thermosetting Resin Sewer Pipe (1995)[73]	Covers specification, evaluation, and testing of materials used in the rehabilitation of existing pipes by the installation and cure of a resin-impregnated fabric liner.
ASTM F 1216 – Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube (1998)[72]	Describes the procedures for the reconnection of pipelines and conduits by the installation of a resin-impregnated, flexible tube which is inverted into the existing conduit by use of a hydrostatic head or air pressure.
NASSCO Specification for Cured-in-place Pipe (CIPP) (as provided by Insituform® Technologies, Inc. for the Insituform® process) (1999)[14]	Describes the specifications, design considerations, materials, equipment, and installation of CIPP installed by inversion.
NASSCO Specification for Cured-in-place Pipe (CIPP) (as furnished by Pipelining Products Inc. for the Cure-Line Pipe® Process) (1999)[14]	Describes the specifications, design considerations, materials, equipment, and installation of CIPP installed by inversion.
NASSCO Specification for Cured-in-place Pipe (CIPP) (as provided by National Envirotech Group LLC for the National Liner™ Process[14]	Describes the specifications, design considerations, materials, equipment, and installation of CIPP installed by inversion.

In addition to the two (2) specific ASTM standards presented in Table 30, the following list of related standards were also associated with the inversion installation method for cured-in-place lining:

- ASTM D 543 – Test Method for Resistance of Plastics to Chemical Reagents[25]
- ASTM D 638 – Test Method for Tensile Properties of Plastics[49]
- ASTM D 695 – Test Method for Compressive Properties of Rigid Plastics (2001)[74]
- ASTM D 790 – Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials[26]
- ASTM D 883 – Terminology Relating to Plastics[70]
- ASTM D 903 – Test Method for Peel or Stripping Strength of Adhesive Bonds[75]
- ASTM D 1600 – Terminology for Abbreviated Terms Relating to Plastics[27]
- ASTM D 1682 – Test Methods for Breaking Load and Elongation of Textile Fabric[76]

- ASTM D 3039 – Test Method for Tensile Properties of Fiber-Resin Composites[77]
- ASTM D 3567 – Practice for Determining Dimensions of "Fiberglass" (Class-Fiber-Thermosetting Resin) Pipe and Fittings[78]
- ASTM D 3681 – Test Method for Chemical Resistance of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe in a Deflected Condition[79]
- ASTM D 3839 – Practice for Underground Installation of "Fiberglass" (Glass-Fiber-Reinforced Thermosetting Resin) Pipe[80]
- ASTM D 4814 – Specification for Automotive Spark—Ignition Engine Fuel[81]
- ASTM F 412 – Terminology Relating to Plastic Piping Systems[31]

Contractors and Manufacturers

A listing of manufacturers and contractors of cured-in-place lining installed by the inversion method is presented in Table 31.

Table 31. Listing of Manufacturers and Contractors of Cured-in-place Lining Installed by Inversion.

Manufacturer/ Contractor	Telephone Number	Fax Number	Address	Coverage Area	Contact Person
Advanced Pipe Inspection, Inc.	(617) 469-6062	(617) 469-3369	P.O. Box 120648 Boston, MA 02112	MA	Joe Walsh
Advanced Sewer Technology, Inc.	(888) 543-1664	(513) 944-4323	9337 Seward Rd. Fairfield, OH 45014	OH	N/A[2]
Allen Electric	(912) 764-9975	(912) 681-2970	P.O. Box 172 Statesboro, GA 30459	GA	Barney Allen
Amethyst Environmental, LTD.	(603) 659-4442	N/A	22 Lee Hill Rd. Lee, NH 03824	NH	Karen Long
Amy Plumbing, Heating & Cooling, Inc.	(847) 742-6523	(847) 742-6791	58 Kimball St. Elgin, IL 60120	IL	James Krenz
AquaLine Services LLC	(303) 684-9631	(303) 684-9631	1903 12th Ave. Longmont, CO 80501	CO	Jeff Anderson
Araco, Inc	(800) 654-0605	(508) 238-8067	920 Washington St. P.O. Box 314 S. Easton, MA 02375	MA, RI, NH, ME, VT, CT	N/A
Associated Products Services, Inc.	(800) 433-2070	(717) 766-4299	2 East Rd. P.O. Box 231 Mechanicsburg, PA 17055	PA	Bill Bonney
Atlantic Pipe Cleaning & Lining Company	(910) 362-0810	(910) 362-0820	4704 N. College Rd. Wilmington, NC 28429	NC	Dale Nichols
Azurix Underground Infrastructure	(800) 547-6193	(407) 260-9668	109 Applewood Dr. Longwood, FL 32750	FL, AL, GA, SC, ME, MA, NH, RI, VT	N/A
Bay Area Environmental Services, Inc.	(813) 677-7655	(813) 677-4457	P.O. Box 1720 Riverview, FL 33569	FL	N/A
Bio Remedies	(915) 590-0163	(915) 590-2228	P.O. Box 26966 El Paso, TX 79926	AZ, TX	Jerry Fannon
Boh Bros.	(800) 248-3377	(504) 821-0714	730 S. Tonti St. New Orleans, LA 70119	LA, MS	N/A
BRH-Garver, Inc.	(713) 921-2929	(713) 921-2487	5402 Lawndale Houston, TX 77023	TX	N/A
Brown Plumbing	(530) 244-7473	(530) 244-1000	3990 Railroad Ave. Redding, CA 96001	CA	Steve Poirier
Commercial Plumbing	(808) 845-4112	(808) 847-1865	1820 Colburn St. Honolulu, HI 96819	HI	Randal Hiraki
D & D, Inc.	(732) 222-6810	(732) 571-2158	2723 West Ave. Long Branch, NJ 07740	NJ	David Gizzi
D.R. Plumbing, Inc.	(412) 885-5300	(412) 885-5302	2526 Library Rd. Pittsburgh, PA 15234	PA	Donald Redinger
Dupree Sewer Service	(847) 746-6403	(847) 746-5972	11323 West 33rd St. Beach Park, IL 60099	IL	Doug Dupree
Dutch Enterprises, Inc.	(573) 243-3193	(573) 243-4370	4832 Old Cape Rd. East P.O. Box 438 Jackson, MO 63755	MO	Bill Bonney
Emergency Service Plumbing	(952) 920-2690	(952) 920-2881	622 Southeast 9th St. Minneapolis, MN 55414	MN	Larry Dawson
Enviro-Flow Companies	(740) 453-9935	(740) 453-8622	4830 North Pointe Dr. Zanesville, OH 43710	OH	Tim Evans
Enviro Pump Plus/Diagnostic Sewer	(507) 734-4661	N/A	1018 County Rd. 63 Balaton, MN 56115	MN	Glenn Larson
Green Bay Pipe & TV Contractors	(920) 490-5501	(920) 490-6242	1768 West Paulson Rd. Green Bay, WI 54313	WI, MI	Tom Debauche

[1]Designates company headquarters, [2]N/A – not available